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THE PROCESS OF CHOICE IN GUESSING GAMES

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Abstract

This paper employs a new experimental design to provide insight into strategic choice in one shot games. We incentivize and observe provisional choices in the 2/3 guessing game in the period after the structure of the game has been communicated. Early selections in this "strategic choice process" data provide insight into naive (L0) play, and support the standard assumption that such choices average 50. While average strategic sophistication rises over time, we identify significant individual differences in this respect. These differences appear to be broad-based: those whose strategic sophistication grows most in our experiment also perform best at separate learning tasks.

1 Introduction

The predictions of equilibrium theory frequently fail when players interact in unfamiliar economic environments. For that reason, non-equilibrium theories focused on strategic sophistication are of growing interest. The game that more than any other sparked this interest is the 2/3 guessing game, in which players select an integer between 0 and 100,

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with the reward going to the individual closest to 2/3 of the group average (Nagel (1995), Stahl and Wilson (1995), Stahl (1996), Duffy and Nagel (1997), Ho, Camerer, and Weigelt (1998), Camerer, Ho and Chong (2004)). While elimination arguments reveal the only equilibrium choices to be 0 and 1, in practice there is significant clustering around 33 and 22. According to "Level k" (Lk) theories, those who pick 22 (type L2 players) are best responding to L1 players who pick 33, who in turn are best responding to L0 players, who are assumed to make a completely random selection, as a result averaging fifty.[1]

This paper employs a new experimental design to provide insight into the process of choice in one shot games. We incentivize and observe the provisional choices of inexperienced players in the 2/3 guessing game in the three minute period after the structure of the game is conveyed to them. The resulting "strategic choice process" (SCP) data capture how internal reflection on the structure of the game causes the perceived optimal decision to change. Unlike other forms of non-standard data designed to provide insight into strategic choice, SCP data come in the familiar form of choices, albeit indexed by time.[2]

We establish four key features of the data.

1. There is a striking match between SCP data and choices in standard games (where only final choice matters) with corresponding time constraints. Play at 30 seconds in the SCP is very similar to play in a standard guessing game with a 30 second time limit, while play at 180 seconds in the SCP closely matches that in a standard 180 second experiment. Thus, the SCP experiment provides information on multiple time-constrained plays of an unfamiliar game by one and the same player.

2. The SCP experiment is designed in such a manner that the early choices subjects make capture their first strategic instincts. For that reason, these choices provide new insight into L0 play. We find that the mean of the initial choices is very close to 50 and the median is precisely 50, in line with the standard assumption.

3. The average level of strategic sophistication changes over time in the SCP data. While the early choices suggest lower strategic sophistication than is typically found

[1] These are focal best responses, not the only best responses: see Breitmoser (2010).

[2] As discussed in section 2.1, examples of such non-standard data are MouseLab, eye-tracking, decision times, verbal reports, and fMRI measurements.

in the 2/3 guessing game, choices at the end of three minutes are very similar to those found in prior experiments.

4. There are important individual differences in how strategic sophistication grows over the contemplation period. These differences appear more general: those whose strategic sophistication grows most in the guessing game also perform better at separate learning tasks involving Bayesian updating.[3] We uncover no such pattern of differential learning based on final choices alone.[4]

While we focus in this paper only on the guessing game, we believe that the impact of contemplation time on strategic decisions is of broader interest. For example, Grimm and Mengel (2010) have recently shown that giving decision-makers additional time to decide in the ultimatum game greatly lowers the rate of rejection of small offers.[5] In addition, Dufwenberg, Sundaram and Butler (2010) have studied games in which a moment of "epiphany" is needed to identify a dominant strategy. Regardless of the precise reason for the change in behavior, we believe that the SCP methodology may be worth deploying in all situations in which contemplation time interacts with strategic choice. In that sense, our experimental design is separable from the theory of strategic sophistication in the 2/3 guessing game.

Background material motivating our experimental design is in section 2, with the design itself in section 3. Connections between the SCP treatment and time constrained Standard Experiments are detailed in section 4. Results on L0 play are in section 5. The time pattern of average strategic sophistication is explored in section 6. Measures of strategic sophistication are considered in section 7. Concluding remarks are in section 8.

[3]The first learning task is modeled on the "Monty Hall" game of Nalebuff (1987), Friedman (1998) and Avishalom and Bazerman (2003). The second is a multiple period Bayesian updating game adapted from Kahneman and Tversky (1972).

[4]This is consistent with the results of Burchardi and Penczynski (2010), and Georganas, Healy and Weber (2010).

[5]One possible reason for this is that the emotional effects of a disappointing offer are felt less sharply once they are internalized. This is a case in which the passage of time may change the decision maker's utility function.

2 Background

2.1 Guessing Games and Non-Standard Data

One question that has guided research on the guessing game is whether choice (say) of 33 is a sophisticated response to a fully reasoned belief that others will average 50 or a reflection of bounds on rationality.[6] In trying to understand this, various researchers have begun to explore non-standard data that may aid in the interpretation of choices. For example, Costa-Gomes, Crawford and Broseta (2001) and Costa-Gomes and Crawford (2006) examined data on information search behavior recorded using MouseLab. Costa-Gomes and Crawford (2006) used MouseLab to study cognition via information search in a rich class of two-person guessing games. They provide compelling evidence that patterns of search as well as of choice can be well explained by Lk and cognitive hierarchy models.

A second line of research involves estimating subjects' levels of reasoning by analyzing verbal data associated with their choices (e.g. Sbriglia (2004), Bosch-Domenech, Montalvo, Nagel and Satorra (2002) and Arad (2009)). Burchardi and Penczynski (2010), for example, analyzed subjects' arguments while attempting to convince their "teammates" to follow their advice.

A separate line of work uses physiological and neurological measurements to gain insight into play in the guessing game. Dickinson and McElroy (2009) find that subjects apply higher levels of reasoning when well-rested rather than sleep-deprived, and when at their peak time of day rather than at their off-peak times. Coricelli and Nagel (2009) use fMRI techniques to explore levels of reasoning in a game in which subjects play against computers. They uncover systematic differences in the neurological responses of the players at different levels of strategic sophistication. Chen, Huang and Wang (2010) used eye-tracking data to complement choice data in a modified 2/3 guessing game played spatially on a two-dimensional plane. Taken together, the above research makes it clear that bounds on rationality play an important role in explaining the behavioral patterns in guessing games.

[6] See Crawford (2008), Grosskopf and Nagel (2008) and Coricelli and Nagel (2009).

2.2 Strategic Choice Process Data

The recent expansion of the evidentiary base in studies of the guessing game mirrors a similar movement in decision theory. The desire to enrich standard choice data while retaining strong links to standard theory led Caplin and Dean (2010) to introduce "choice process" data in the search theoretic context. These data identify the evolution of perceived optimal choices during the period of search. Caplin, Dean, and Martin (2010) develop an experimental interface to capture these data, and use it to get new insights into the nature of the search process and the rules for stopping search.

The current paper is the first to use the choice process design to study strategic decision-making. Unlike in the search theoretic context, in the strategic case there is no external information to gather that would motivate changing one's mind in the pre-decision period. Hence the question our SCP experiment addresses is the extent to which subjects learn to play the guessing game by turning it over in their mind. As they do this, they may reflect both on the structure of the game itself and on their own earlier thoughts (as in the Goeree and Holt (2004) model of "noisy introspection"). Do they gradually move to higher levels of strategic sophistication as they internalize the structure of the game? Do they use their own earlier thoughts to model the thoughts of others, as suggested by various models in social psychology (see Dawes (1990))? The SCP experiment gathers data on this process of learning while hewing closely to the decision theoretic tradition.

2.3 Learning by Thinking and Time To Decide

Economists have studied many forms of learning, such as Bayesian updating, learning by doing, and reinforcement learning. Our focus is on a quite distinct form of learning that involves no new external stimulus: "learning by thinking." This raises the question of how long a period of time players have been given to contemplate their strategy in prior versions of the guessing game. Unfortunately there is little pattern in this respect. Ho, Camerer and Weigelt (1998) set an experimental time limit of 2 minutes. However this was the maximum allowed time and not the time it took for subjects to actually respond. Bosch-Domenech, Montalvo, Nagel and Satorra (2002) report results of a five minute laboratory experiment, and of other experiments conducted more remotely (e.g. via newspaper) with response times of up to two weeks.

We are aware of only one paper in which the time constraint in a 2/3 guessing game was manipulated. Kocher and Sutter (2006) examined the effects of time pressure and incentive schemes on choices in repeated plays of the guessing game. Surprisingly, they did not find much difference in first round play for different time constraints.[7]

Using a different design, Rubinstein (2007) explored the connection between contemplation time and choice in the context of an online version of the guessing game. There was no maximum time, but a server recorded the time a subject took to submit the answer. He found that the focal L1 and L2 responses of 33 and 22 respectively took longer on average than other choices.

In a particularly relevant precursor to the SCP design, Weber (2003) also explored the connection between contemplation time and choices in the guessing game. He had subjects play the guessing game ten times in a row, providing them with no feedback on their performance until all ten trials had been completed. What he found was that, while choice in the first round was entirely as in the standard game, by round ten the average choice had fallen significantly. This suggests that further reflection on the structure of the game led many to change their minds, without any feedback from outcomes and without new external information of any kind.

In Weber's (2003) setting, subjects may change their decisions over time not only due to continued reflection on the structure of the game, but also because they expect others to change. In contrast, our SCP experiment is designed exclusively to focus on the impact of internal reflection.[8]

[7]This may be due to the fact that their subjects knew that they would repeat the game several times, and so would be able to change their decisions in later plays of the game. In our design, subjects play one and only one time, and may therefore more rapidly internalize the structure of the game.

[8]This is because the other payoff-relevant actions were settled in a prior interaction as we will describe in the next section.

3 The Experimental Design

All of the experiments were run at the laboratory of the Center for Experimental Social Science (CESS) at New York University. Subjects were drawn from the general undergraduate population in the university by email solicitations. The guessing game experiments themselves lasted about 10 minutes. Subjects in the SCP treatment participated in an additional series of tasks, as detailed in section 3.3 below. Average payoffs were between 10 and 15 dollars.

In all treatments, subjects were first seated at their computer terminals, and then given the experimental instructions, face down. Once all subjects received their instructions, they were instructed that they could turn the sheets over and the instructions were read out loud. Subjects did not communicate with one another during the experiments. There was only a single play of the 2/3 guessing game in each experiment. The precise experimental instructions differed across treatments as indicated below.

Given our interest in how learning takes place in a novel one shot game, we dropped subjects who reported being familiar with the game, whether in a lab, in a classroom or in any other context. This familiarity was assessed in a questionnaire at the end of each session. Some 25% of subjects had either played the game or heard of it. The remaining sample consists of 188 subjects.

3.1 Standard Guessing Games

Before running the SCP experiment, we conducted standard guessing games of 30 seconds and 180 seconds durations. In these games only the final choice of each subject mattered for payment. The longer time of 180 seconds was chosen since prior work suggests that it is enough time for most subjects to reason through the game, while the shorter time was chosen to cut short such reasoning. These Standard Experiments were included not only to gauge the importance of decision time in the outcome of the game, but also to provide benchmarks with which to compare the SCP treatment. In total, 66 subjects participated in the 30 second treatment, and 62 participated in the 180 second treatment.

The rules of the game and the task were described as follows:

RULES OF THE GAME: A few days ago 8 undergraduate students like yourselves played the following game. Each of the 8 students had 180 seconds to choose an integer between 1 and 100 inclusive, which they wrote on a piece of paper. After 180 seconds, we collected the papers. The winner was the person whose number was closest to two thirds of the average of everyone's numbers. That is, the 8 students played among themselves and their goal was to guess two thirds of the average of everyone's numbers. The winner won $10 and in case of a tie the prize was split.

YOUR TASK: You will have 180 seconds to choose an integer between 1 and 100 inclusive. You win $10 if you are "better than" those 8 students at determining two thirds of the average of their numbers. That is, you win $10 if your number is the closest to two thirds of the average of the numbers in the past game.

OR

YOUR TASK: You will have 30 seconds to choose an integer between 1 and 100 inclusive. You win $10 if you are "better than" those 8 students at determining two thirds of the average of their numbers. That is, you win $10 if your number is the closest to two thirds of the average of the numbers in the past game.

The screen displayed 100 buttons, each representing an integer between 1 and 100 inclusive.[9] Once the game started, subjects could select any number by clicking on the button displaying it. Subjects could change their selected number as many times as they wanted. Subjects could end the game earlier by clicking on a "Finish" button. There was no difference between choosing a number and staying with that number until the end of the game or instead clicking the Finish button. In the Standard Experiment, it was only their final choice (at 30 seconds or 180 seconds as specified in the instructions) that determined the participant's payoff from the game.[10]

[9]It is common to allow also the choice of zero. Having the minimum choice be 1 simplifies matters in that the unique Nash equilibrium, identifiable by iterated elimination of dominated strategies, is for all to select 1. In contrast, when zero is included as an option, there are multiple equilibria. It is also common to allow subjects to choose any real number, as opposed to integers. Our experimental apparatus - displaying all the possible choices on the screen - makes the restriction to integers a necessary one. The equilibrium is unchanged by this modification.

[10]There was no incentive to finish early, since the game lasted the same amount of time regardless.

Note that our experiment has the feature that a subject's number is not included in the average. This ensures that the corresponding SCP treatment does not have additional equilibria. In technical terms, this makes the game analogous to a standard guessing game with a large number of participants (see Bosch-Domenech et al. (2002)).[11]

3.2 SCP Treatment

While there was no change in the described rules of the game, what determined the subject's payment in the SCP treatment was the subject's choice at a random time.[12] The experimental instructions were as follows.

> When the game starts, you can select a number by clicking on the button displaying the number that you want. You may click when you want, however many times you want. The computer will record all the numbers you click on, as well as when you clicked on them. After 180 seconds, or when you click the finish button, the round will come to an end and you won't be able to change your choice anymore. Just to make clear, if you choose a number and then stay with that number until the end, or instead decide to click on the "Finish" button, it will make no difference.
> Only one of the numbers you selected will matter for payment. To determine which one, the computer will randomly choose a second between 0 and 180, with each second equally likely to be chosen. The number you selected at that time will be the one that matters. We will call this number **"Your Number."**

We took measures to ensure that subjects participating in SCP treatments properly understood the incentive structure. Hence when they arrived in the lab we described the experimental methodology to them before introducing them to the guessing game. They were told that:

1. The game that they were about to play would last 180 seconds.

[11] Formally: suppose the group size is n and a subject believes the average of the other participants is $\bar{x}$. If that subject's number is counted in the average then that subject should choose $\frac{2(n-1)\bar{x}}{3n-2}$ so that as the group size gets larger and larger, this choice converges to $(2/3)\bar{x}$, which is what the subject should choose if his/her number were not counted in the average.

[12] In this treatment, it was the choice of a subject at a random second that was compared to the choices of the 8 subjects that had played the game previous to the experiment.

2. The computer would record their choice throughout the game.

3. After the 180 seconds were over, the computer would randomly select one of the 180 seconds.

4. Their choice at that random second would be the one that mattered for their payment.

Illustrative examples were provided to illuminate the nature of the final payoff.[13] The examples illustrated that failure to pick an option would result in a certain payoff of zero. Hence subjects in the SCP treatment were incentivized to make a quick and intuitive first estimate of two-thirds of the average final number picked by the group that had played previously. Whenever further reflection causes this best estimate to change, they were incentivized immediately to make the corresponding change in their guess.

3.3 Other Tasks in the SCP Treatment

Following their participation in the SCP treatment, subjects were presented with a series of questions. The full set of these questions is in Appendix B.[14]

Some of the questions that were posed were designed to elicit standard individual characteristics, in particular risk aversion and various aspects of numeracy.[15] Of the remaining questions, several were designed to explore whether differences in the degree of learning exhibited in the SCP treatment were connected with ability to update in the face of new external information (see "The Monty Hall Problem" and the "Multiple Period Bayesian Updating" problems described below). A final set of questions was designed to explore a possible connection between status quo bias and the path of learning (see "Status-quo Lottery Choice" below).

1. **The Monty Hall Problem.** This is a classic problem in which intuition can diverge from Bayesian reasoning. We showed participants three closed doors on the

[13] Appendix A contains the complete instructions for these SCP sessions.

[14] Appendix B comprises all games with which every subject was involved.

[15] To evaluate risk aversion we used the method of Holt and Laury (2002) - See Appendix B.5. For the numeracy questions we used questions from the Health and Retirement Survey, which have been used by Banks and Oldfeld (2007) and Burks, Carpenter, Gotte, Monaco, Porter and Rustichini (2008), as well as the Cognitive Reflection Test, which has been used by Frederick (2005) among others - See Appendix B.4.

screen, and let them know that there was \$5 behind one and only one randomly chosen door, with nothing behind the other two. They were then asked to choose one of the doors. At that point, the experimenter announced that he or she knew the location of the \$5, and opened one of two unselected doors to show that it contained nothing. The subject was then given the option either to stay with their initial choice or instead to switch to the other closed door.

2. **Multi-Period Bayesian Updating.** This is a dynamic version of the Kahneman and Tversky (1972) "Taxi Game". Subjects were told that 90 out of 100 cabs in a city were green, the others blue. They were also told that "witnesses" correctly identify the color of a cab 70% of the time. The game lasted seven periods. Each period a witness came forward and announced she had seen the cab and it was of a particular color. It was explained that each witness was independent of the previous ones. Subjects were asked to report the chances of the cab being green after each new witness came forward.

3. **Status-quo Lottery Choice.** There were two stages in these games, and each subject played three such games. In the first stage, students were faced with three lotteries and were asked to choose one among them. This lottery became the "status-quo" lottery for the second stage. In the second stage, subjects could choose to keep their first lottery or switch to a specified alternative.[16]

4 SCP and Time Constrained Games

By definition, a subject can play an unfamiliar game one and only one time. This poses a challenge for those seeking to understand how the contemplation period interacts with the final decision. For one so interested, the standard procedure (between subject design) requires the use of separate pools of subjects for each time constraint (since by definition, the same player cannot be used twice). Therefore, the standard procedure does not easily and cost-effectively allow the identification of individual learning differences.[17] It is little wonder that there has been little research on the subject.

[16]See Samuelson and Zeckhauser (1988).

[17]At the very least, it requires a large sample to adequately control for individual differences.

The SCP experiment is designed to elicit from one individual an entire sequence of time-constrained choices in their very first play of an unfamiliar game. The extent to which this design provides information on how time constraints impact play depends on whether or not the choices it gives rise to are different than those in the corresponding sequence of time-constrained games.

Our experimental design allows us to investigate this issue based on the Standard Experiments that were conducted with 30 and 180 second time constraints. In Table 1 we present summary statistics of choices in the Standard Experiments with the 30 and 180 second time limits, and the choices after 30 seconds and after 180 seconds in the SCP treatment.

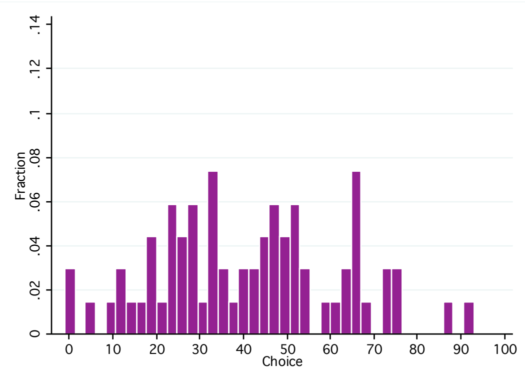
	mean choice	std deviation	# of obs
30 seconds - Standard	42.83	20.13	66
30 seconds - SCP	41.68	19.95	60
180 seconds - Standard	36.35	20.24	62
180 seconds - SCP	36.73	18.34	60

Table 1: Summary Statistics of Choices in Standard and SCP Treatments.

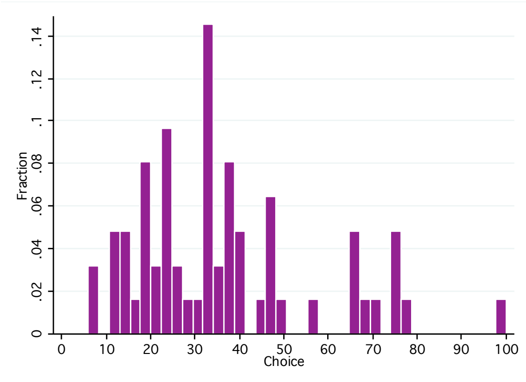
The table displays the strong similarity between the SCP treatment and standard guessing games of equivalent horizon. A two-sample Wilcoxon ranksum (Mann-Whitney) test comparing the full distribution of 30 second choices in the SCP and in the Standard Experiment shows that we cannot reject the hypothesis that the two samples are from the same distribution ($p > 0.10$). Similarly, a two-sample Kolmogorov-Smirnov test for equality of distribution functions gives us the same results ($p > 0.10$). The same holds true when comparing the 180 second choices in the SCP and Standard Experiments. Figure 1 below displays the histogram of choices in the Standard 30 second and 180 second treatments and SCP experiments at 30 and 180 seconds.

The results at 180 seconds in the SCP treatment and in the 180 second standard treatment are not only similar to one another, but also similar to those identified in the pioneering work of Nagel (1995), Ho, Camerer and Weigelt (1998), and Camerer, Ho and Chong (2004).[18] The previous literature suggests two measures of strategic sophistication: Nagel (1995) and Camerer, Ho and Chong (2004). We find the Nagel (1995) classification to exclude many of the early respondents, hence our central estimates of the the type

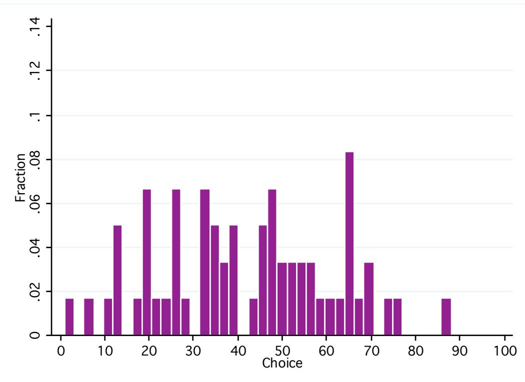
[18]See Appendix D.



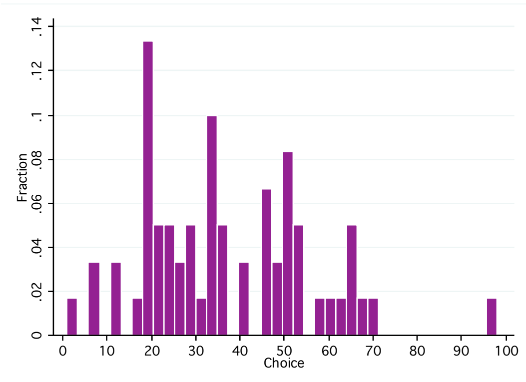
(a) Standard Experiment - Choice at 30 Seconds



(b) Standard Experiment - Choice at 180 Seconds



(c) SCP Experiment - Choice at 30 Seconds



(d) SCP Experiment - Choice at 180 Seconds

Figure 1: Histogram of Final Choices in the Standard and SCP Experiments

	# obs	Mean (Data)	τ	Bootstrap 90% C.I.
30 second treatment	66	42.83	0.5	$[0, 0.25]$
SCP at 30 seconds	60	41.68	0.6	$[0, 0.31]$
180 second treatment	62	36.35	1.1	$[0.41, 1.33]$
SCP at 180 seconds	60	36.73	1.06	$[0.45, 1.72]$
Ho, Camerer and Weigelt (1998) $p = 0.7$	69	38.9	1	$[0.5, 1.6]$
Nagel (1995) $p = \frac{2}{3}$	66	37.2	1.1	$[0.7, 1.5]$

Table 2: Estimating τ in the Standard and SCP Experiments, Comparison with Nagel (1995) and Ho, Camerer and Weigelt (1998).

distribution in the SCP game are based on the cognitive hierarchy (CH) model of Camerer, Ho, and Chong (2004).[19] In Table 2, we report the best fitting estimate of their τ parameter as well as the 90% confidence interval for τ from a randomized resampling (with replacement) bootstrap procedure. The table clearly indicates the similarity between play at 180 seconds in our SCP treatment, in our Standard Experiment, and in the prior work of Nagel (1995) and Ho, Camerer and Weigelt (1998).

We conclude that indeed there are strong similarities between SCP data and data on the corresponding sequence of time-constrained games. The SCP treatment appears to be, to a first approximation, equivalent to multiple guessing games with different time constraints. In addition to allowing one to economize on the number of plays, using the SCP treatment to explore the impact of time constraints removes the need to control for individual differences: the players are one and the same regardless of the time constraint.

5 L0 Play

5.1 The Measurement Challenge

Assumptions concerning the choices made by L0 players are foundational in models of strategic sophistication. In order to characterize the actions of higher level players one

[19] The process begins with Level 0 players, who are assumed to play according to a uniform distribution. Level k thinkers assume that the other players are distributed according a normalized Poisson distribution (with parameter τ) from Level 0 to Level k-1. Hence they correctly predict the relative frequencies of Levels 0 through k-1, but may incorrectly believe that they are the only player of Level k and that there are no players more sophisticated than they are. The estimation of τ involves finding the value of τ that minimizes the difference between the observed sample mean and the mean implied by τ."

must make make explicit assumptions concerning the choices of these "non-strategic" players. A particular difficulty in this regard is that conjectured L0 types appear to be few and far between in most games. Hence in order to test a particular a priori theory of L0 play it is standard to explore patterns in final choices that reflect iterative best responses to L0, with the presumption that L1 and L2 players are most common.

The guessing game is a case in point. A seemingly natural conjecture in the guessing game is that L0 players make choices that are uniformly distributed over the range [0,100], hence averaging 50 (see, for instance, Nagel (1995), Stahl and Wilson (1995) and Camerer, Ho and Chong (2004)). While this may be a priori plausible, it is the experimental finding that many select numbers close to 33 and 22 that provides most comfort on this assumption, at least for proponents of the Lk theories. However, the behavioral evidence is far from definitive, resting as it does on the twin hypotheses that Lk theory is correct, and that L0 and L3 types are less prevalent than L1 and L2 types.

Given its importance and the difficulty of making inferences based on final choices alone, there is interest in using non-standard data on choice procedures to gain additional insight into L0 play. In a recent example of such non-choice based inference, Burchardi and Penczynski (2010) use a novel design in which players in the guessing game are divided into teams, with each member being allowed to pass both their individually preferred choice and a persuasive message to their partner concerning how best to play the game. Burchardi and Penczynski (2010) classify these arguments according to level of strategic sophistication in a manner that turns out to align well with the associated choices. In particular, for those classified in this manner as being L0 types, the mean action was 58.

While intriguing, the approach adopted by Burchardi and Penczynski (2010) rests on a large number of intermediate hypotheses and on a novel version of the guessing game. The method that we outline in this section is considerably easier to implement, and does not rely on subjective interpretations of verbal responses.

5.2 First Choice, First Decision Time, First Revision Time

The SCP treatment was designed to provide us with information on each participant's strategic first thoughts. To that end, subjects were incentivized to make quick and instinctive choices as soon as the structure of the game had been conveyed to them. As described in section 3, they were introduced to the choice process incentive scheme before they learned the rules of the guessing game. Hence they knew that failure to make an immediate choice was a dominated strategy. It was made clear in the instructions that if they failed to make any selection at the random stopping time their payoff would be set to zero. As a result, they had every incentive to make a quick first guess rather than delaying to think more deeply through the structure game.

Most subjects followed the SCP incentive and made their first choice in short order. The median (and mode) first choice time was 6 seconds. By the 10^{th} second, 85% of our subjects had made a first choice.

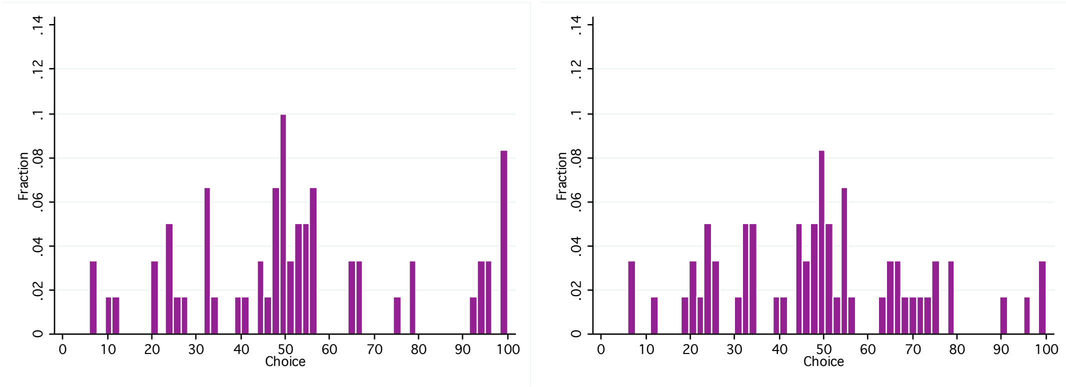
A natural way to investigate L0 play is to look at subjects' very first choices. However, a possible concern is that the first choice may not indicate L0 play but instead be a random "panicked" choice generated by our incentives to choose a number quickly. Hence we consider also the "Modified First Choice" defined as the first choice if a subject stayed on that number for at least five seconds, and otherwise the second choice, which may, in this situation, be a better indication of L0 play.[20] Figure 2 comprises two histograms. The first is the histogram of the very first choices of subjects, the second is the distribution of modified first choices. Table 3 presents key statistics concerning these two measures of L0 play. While average play is similar between very first choices and modified first choices, note that there is a significant difference in the size of the spike at 100: it apparently takes little time for most to realize that this is not the best choice.

As Figure 2 shows, L0 choices are approximately uniform (in both measures), albeit with a noticeable spike at 50.[21] The mean L0 choice is close to 50,[22] as are the median and mode. To a first approximation, our SCP experiment provides support for the standard

[20] A choice of a 10 second cutoff does not change findings described below.

[21] Figure 2(a) also has a spike at 100. While the number of subjects choosing 100 declines to almost zero after three minutes, there are quite a few subjects who choose 50 even after the full 3 minutes.

[22] A random sampling with replacement bootstrap procedure gives a mean first choice of 49.4 and a 95% Confidence Interval for the mean of $[42.5, 56.2]$.



(a) First Choice (b) Modified First Choice

Figure 2: Histogram of L0 play

	First Choice	Modified First Choice	Time Spent on First Choice Conditional on Switching
Mean	53.1	50	18.8
Median	50	50.9	10
Standard Deviation	25.57	21.9	23.7
Time of the choice	mean: 7.2 sec st dev: 4.75	mean: 8.1 sec st dev: 4.8	NA

Table 3: Summary Statistics of First and Modified First Choices.

assumption that L0 types average 50.[23]

6 Time and Strategic Sophistication

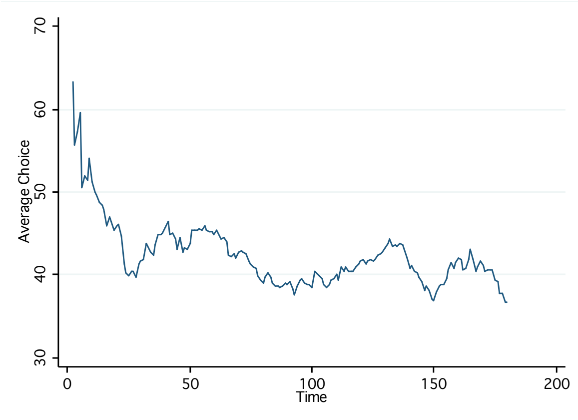
Table 2 shows that average choices are significantly lower at 180 seconds than at 30 seconds, both in the SCP and Standard Experiments (confirmed by estimates of τ at 30 and 180 seconds). This implies that, on average, subjects advance in strategic level as they have more time to think about the game. Figure 3(a) generalizes this finding by plotting average choices as a function of consideration time in the SCP treatment.[24] Regression analyses using both linear and fractional-polynomial formulations confirm that average choices display diminishing time trends.[25] The regression plots and corresponding 95%

[23]Our standard 180 second experiment provides further support for the identification of average L0 choice as 50. Indeed, the average and median first choices in that experiment, for those choices made within 30 seconds of the start of the game, are both close to 50.

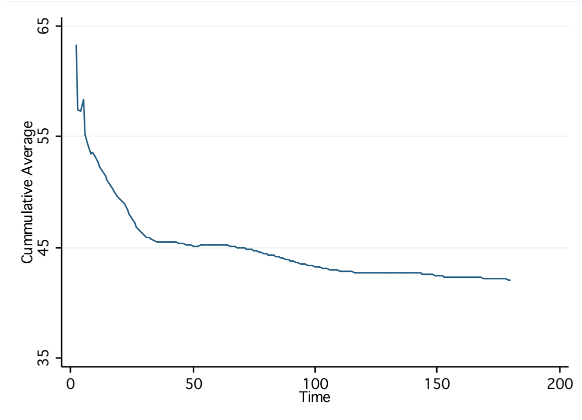
[24]While Lk theory does not explicitly incorporate time, those with higher cognitive levels are treated as reasoning further through the game. Hence one might expect their choices to decrease over time. For more details on Lk see Appendix D.

[25]The graphs are similar for median choices over time.

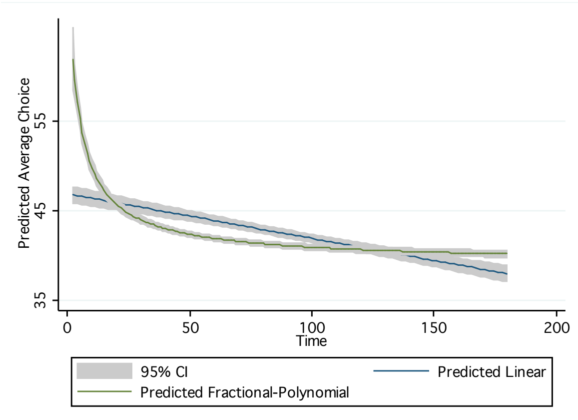
confidence intervals are in Figure 3(c).



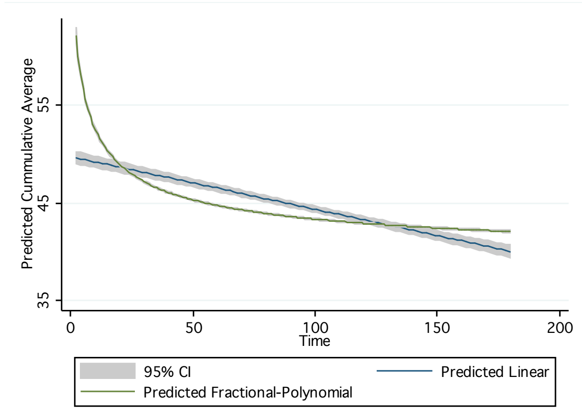
(a) Average Choices Over Time



(b) Cumulative Average Choices Over Time



(c) Predicted Average Choice Over Time



(d) Predicted Cumulative Average Choice Over Time

Figure 3: Average Choices Over Time: Raw Data and Regressions

An alternative approach to understanding the dynamics of choice over time is to compute the cumulative average. Recall that in the SCP treatment each of the 180 seconds has the same probability of being chosen for payment. Therefore, the participant who chooses the same number X in all 180 seconds can be seen as choosing X 180 times. This is taken into account in Figures 3(b) and 3(d) which average over current and past choices to arrive at the cumulative average choices over time. Note that the declining pattern in the cumulative average choice is smooth and well matched by the non-linear formulation.[26]

The simplest form of introspective reasoning by which a subject may advance in type is based on best-responding to own past decision, which results in selecting precisely 2/3

[26]Surprisingly, the decreasing pattern is also present in the Standard 180 second experiment, despite the fact that in that treatment subjects were not incentivized to reveal intermediate thoughts.

of the previous choice (a rapid learner might pick some power of 2/3 by skipping levels of reasoning). One subject (subject 31) fit this pattern precisely, moving from 50 to 33 to 22, and retaining this choice for the remainder of the 180 seconds. In total, 8 out of 60 subjects at some point display such two thirds thinking. Even though the percentage of such adjustments is non-negligible, it is far from the dominant feature of our data.

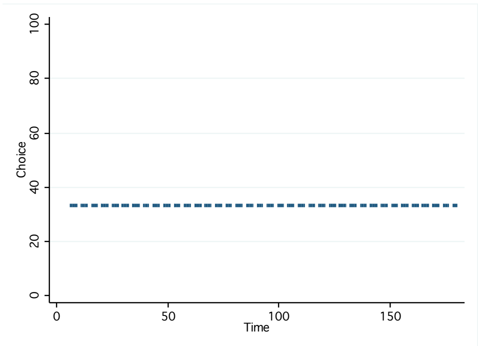
7 SCP Types

The existing experimental literature on the guessing game suggests that there is little correlation in level classifications across games when classifications are based only on final choices. There is some evidence that at the population level the distribution of types across games may be stable (see for example Camerer, Ho and Chong (2004)). At the individual level, Georganas, Healy and Weber (2010) find that though there is a correlation of levels within guessing games, choices in the guessing games fail to correlate with behavior outside the guessing game family. Burchardi and Penczynski (2010) reach similar conclusions. In this section we indicate the potential value of focusing on the path of play rather than on the final level of play.

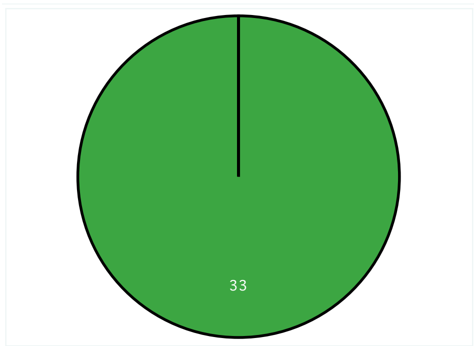
7.1 Heterogeneity

One possible reason for the failure of types defined by level of reasoning to generalize is that they do not adequately summarize strategies, particularly when learning is taking place. To drive home this point, Figure 4 presents three individuals whose final choice is the same (33), and who would be classified as L1 thinkers if only their final choice was observed. However, the manner in which they arrived at this final choice is dramatically different, and may contain information of great value in understanding their behavior in various settings. These and all other complete paths of choice are in Appendix F.

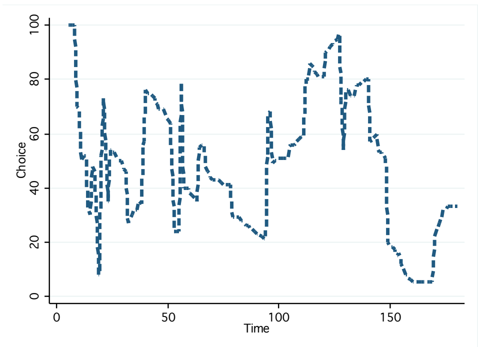
Figure 5 provides additional evidence for heterogeneity. It plots the distribution across the population of the fraction of switches in the downward as opposed to the upward direction. Despite the decline in the average population choice over time, a relatively large mass of subjects made approximately the same number of upward as downward



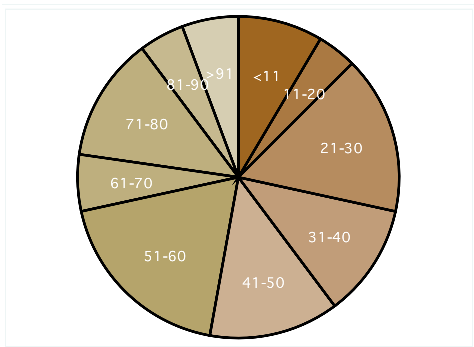
(a) Subject 57: Time Path of Choices



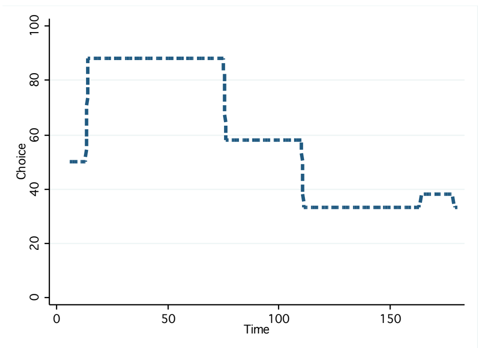
(b) Subject 57: Fraction of Time on Choices



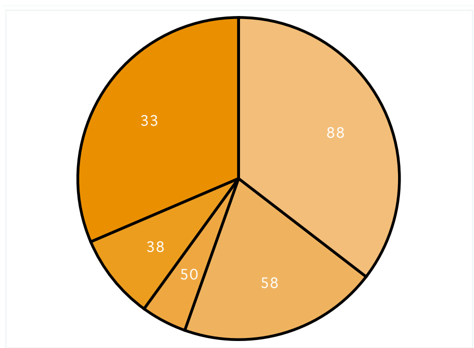
(c) Subject 54: Time Path of Choices



(d) Subject 54: Fraction of Time on Choices



(e) Subject 58: Time Path of Choices



(f) Subject 58: Fraction of Time on Choices

Figure 4: Is Final Choice Enough? Paths of Choice for Three Individuals With the Same Final Choice.

adjustments.

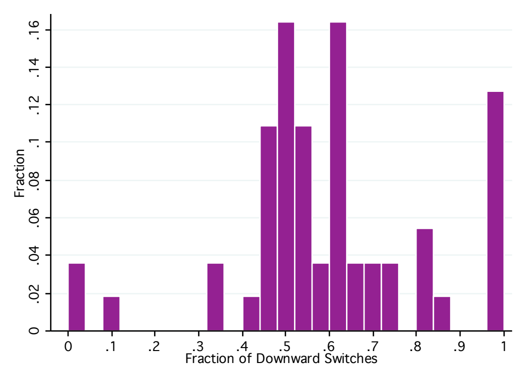


Figure 5: Histogram of fraction of downward switches.

7.2 SCP Types

Given that there appear to be large individual differences in switching behavior, we classify subjects into types based on an overall measure of their change of play over the course of the game. Specifically, we compare the average of each subject's selection in the first 50% of their choices with the corresponding average over their remaining choices. This prescription is exact for an individual who makes an odd number of switches, for whom we compare the average number associated with the first half with the corresponding average in the second half, weighting by the amount of time spent on each number.[27] With an even number of switches we arbitrarily assign the additional choice to the first half (this distinction is irrelevant in practice).

Figure 6 shows the distribution of the percentage average difference between the choices in the first half versus the second half.[28] We use this comparison to define three behavioral types, as follows:

- **Constant**: Those for whom the 2$^{\text{nd}}$ half average is within 20% of the 1$^{\text{st}}$ half average: there are 34 such subjects (56.7% of the population).[29]

[27] Normalizing the change in average play by the standard deviation of choices to incorporate a measure of the volatility of play generate the same qualitative results. The quantitative results are available from the authors upon request.

[28] For each subject: $\frac{\text{Average Second Half - Average First Half}}{\text{Average First Half}}$.

[29] The qualitative results do not change if we use cutoffs of 10, 15, 25 or 30% instead of 20%.

- **Decreasing**: Those for whom the 2nd half average is 20% or more below the 1st half average: there are 18 such subjects (30% of the population).

- **Increasing**: Those for whom the 2nd half average is 20% or more above the 1st half average: there are 8 such subjects (13.3% of the population).

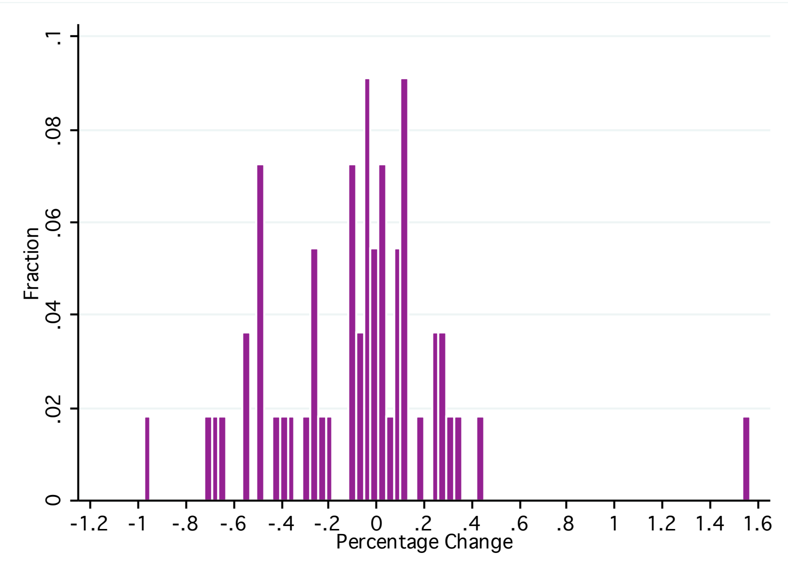


Figure 6: Distribution of percentage difference in the averages between the second and first halves of choices.

Table 4 below presents some statistics concerning these behavioral types.

	Constant	Decreasing	Increasing
Time of first choice	7.73 sec	6.72 sec	6 sec
First choice (mean)	50.88	56.61	54.75
1st half average	43.51	50.36	41.92
2nd half average	44.08	25.40	60.11
Last choice (mean)	38.68	24.1	57

Table 4: Summary Statistics for the three behavioral types.

There are several dimensions along which these behavioral types are indistinguishable. First, they do not differ in our measures of numerical ability.[30] Hence there is no broad-based difference either in general cognitive ability, or in the degree of attentiveness during the course of the experiment. Second, early choices do not differ across behavioral types.[31] In fact, there is no difference in first half average choices. It is only as time progresses

[30] See Appendix C for the results.

[31] A two-sample Wilcoxon ranksum test as well as a Kolmogorov-Smirnov test cannot reject the equality of distributions of first choices. The lowest pvalues are greater than .5.

that the types separate out. As a result, the average final choices are lowest for the Decreasing types, while those for the increasing types are highest. Statistical tests on the final choices of the Constant, Decreasing and Increasing types shows that pairwise these behavioral types are statistically different.[32]

In terms of their performance in the guessing game, the students that played the game before the Standard and SCP experiments had an average of 38, which makes 25 the best choice in our SCP treatment. Table 4 shows the Decreasing group performed better than others in our game.

7.3 The Monty Hall Game

In the Monty Hall game (see section 3.3), appropriate updating implies that the respondent should switch doors, yet it is intuitively plausible that it is equally good to stick with the initial choice. Table 5 below presents the results of four Probit regressions from the Monty Hall game. The dependent variable y_i equals 1 if participant i kept the initially chosen door and 0 otherwise. Regression 1 and 2 use final choice and Nagel's types as independent variables, respectively.[33] In Regression 3, the independent variable is a dummy equal to 1 if a subject is classified as a Decreasing type. In Regression 4, we add the interaction between final choice and Decreasing type as an independent variable.[34]

Table 5 clearly shows that the regressions that uses our behavioral types as predictors have statistically significant coefficients. In other words, the final choice of subjects in the guessing game does not correlate with behavior in the Monty Hall game. However, as apparent from Regression 3, belonging to the Decreasing type is a predictor of play in the Monty Hall game. Further, individuals who belong to that category are more than

[32]The ranksum test p-values are 0.0019 for the test on the Decreasing type versus Constant, 0.0007 for Decreasing versus Increasing and 0.0292 for Constant versus Increasing. The p-values are similar for the Kolmogorov-Smirnov test. Thus we can reject the null that the pairwise comparison come from identical distributions.

[33]Regression 2 uses dummy variables for the L1 and L2 types as defined by Nagel (1995), leaving the L0 type as the control group. There was only one subject in the L3 category. This observation was dropped from the analysis. See Appendix D for more on the Nagel (1995) types.

[34]As mentioned in section 7.2, using a definition for decreasing in which the change in average choice is normalized by the standard deviation of choices yields the same results. This is also true if we use a 10, 15, 20 or 30% cutoff for the definition of Decreasing. In addition, using the continuous measure of the percentage average change over the two halves of the game confirms the significance of the path rather than the final choice in explaining behavior in the Monty Hall game. All of these results are available from the authors upon request.

	Regression 1	Regression 2	Regression 3	Regression 4
Decreasing			$-0.7364^{**}(0.371)$	-2.8739^{***} (1.087)
Dec. × Final Choice				0.0899^{**} (0.0427)
Final choice	0.0128(0.009)			-0.0054 (0.0117)
Level 1 (Nagel)		0.4745(0.682)		
Level 2 (Nagel)		$-0.6980(0.572)$		
Constant	0.1680(0.366)	$0.9085^{**}(0.440)$	$0.8761^{**}(0.223)$	1.108^{**} (.5541)
# of obs	60	35	60	60
Log Likelihood	-33.8016	-16.8079	-32.8156	-29.4435
Pseudo R^2	0.0285	0.1066	0.0569	.1538

Coefficient and standard deviation is reported in the parenthesis
** - significant at 5% *** - significant at 1%

Table 5: Predicting behavior in the Monty Hall Game.

twice as likely to switch doors after they receive new information on which door does not contain the prize money.[35] Regression 4 shows that adding the interaction term does not change the significance or the sign of the coefficient in front of the "Decreasing" dummy. The positive sign of the coefficient of the interaction term shows that among those who are in the decreasing group, those who end up with a lower final choice are also more likely to switch door.[36]

In intuitive terms, this suggests that Decreasing types are better than others at incorporating new information, whether this information results from internal reflection or a change in the information set on which to base a decision.[37]

7.4 Multi-Period Bayesian Updating

The connection between Bayesian updating and our SCP types was also apparent in our multiple period Bayesian updating game. In Table 6 we show summary statistics on the choices of individuals depending on whether they are of the Decreasing type.[38] The Decreasing and non-Decreasing types have strikingly different averages. Further, the

[35]In the data, some 44% of those who belong to the Decreasing type switch door, while fewer than 20% of those who do not belong to the Decreasing group switch door. A test of proportions confirms that this difference is signficant. The two-sided p-value for the test of proportion is 0.0415, rejecting the null that the probability of switching door is the same for both the people in the Decreasing group and for those not in the Decreasing group.

[36]Marginal effects probit regressions (for Regressions 3 and 4) are in Appendix E.

[37]We find no such relationship with status quo bias, the test for which is also outlined in section 3, with results in Appendix C.

[38]Breaking down the non-Decreasing type into Constant and Increasing does not change the qualitative results: the Decreasing types behave differently than the others.

error in prediction is always higher for the non-Decreasing types.

		Non Decreasing		Decreasing	
Period	Theory	Mean	Error	Mean	Error
1	20.6	53.4	32.4	43.6	23
2	37.7	64.9	27.2	55	17.3
3	58.5	70.4	11.9	63.9	5.4
4	37.7	65.8	28.1	48.6	10.9
5	58.5	74.3	15.8	61	2.5
6	37.7	63.5	25.8	45.3	7.3
7	58.5	69.2	10.7	56.1	-2.4

Table 6: Results by behavioral type.

As in the SCP treatment, the early behavior of the various types is not easy to distinguish: both Kolmogorov-Smirnov and Ranksum tests shows no difference between types in period 1. Yet this difference is significant for each of the ensuing periods (2 through 7).[39] While the identification of correct updating is more intricate than in the Monty Hall game, the central finding is that Decreasing types show behavior indicative of faster learning. For example, while non-Decreasing types appear never to choose in a manner that is consistent with Bayesian updating,[40] the Decreasing types do not significantly diverge from the Bayesian solution except in the first two periods.[41] In addition, the individual errors are significantly smaller for the Decreasing types.[42] A regression using "Total Squared Error" [43] as a dependent variable and Decreasing Type as an independent one, as well as our numerical ability measures, shows that being in the Decreasing group implies a significantly lower squared error.[44,45]

One question the above raises is precisely how the non-Decreasing types come to make such large and continuing errors. One possibility would be overshooting, in which they

[39] The pvalues for Ranksum tests comparing the answers between those in the Decreasing group versus those not in the Decreasing group for each of the seven periods are (in order): 0.2065, 0.0685, 0.0797, 0.0187, 0.0369, 0.0117, 0.0408. The pvalues are similar for the Kolmogorov-Smirnov test.

[40] The largest pvalue in a series of signrank tests is .0329. Thus, for each period we can reject the null that the mean of the subjects' answers are equal to the theoretical prediction.

[41] For periods 3 through 7, smallest pvalue in a series of signrank tests is greater than 0.10.

[42] This does not follow from the previous point. Indeed, if one group had half the people choosing "Theory + X" and half choosing "Theory - X", while in the other all chose "Theory - ϵ", then with the signrank test the former would on average target the theory while the latter would not.

[43] Each subject's "Total Squared Error" is $\sum_t(\text{Theory}_t - \text{Choice}_t)^2$.

[44] The coefficient on Decreasing is -4,088 with a p-value of 0.002. The adjusted R-squared is 0.1372.

[45] These results are largely confirmed when performing individual period regressions with "squared error in period t" as the dependent variable and behavioral type - and even our numerical ability measures - as dependent variables (the ability measures are never significant).

adjust overly much to the new information that is provided by each witness. The other is under-adjustment. To identify which is the case, note that the percentage difference in mean prediction between periods is smaller for the non-Decreasing types than for the Decreasing types. For example, the difference in mean choices between periods 1 and 2 is 21.5% for the non-Decreasing types, versus 26.1% for the Decreasing types.[46] This simple examination of the evidence, together with the fact that the non-Decreasing types do not target the theory, suggests that under-adjustment may be predominant: the non-Decreasing types appear to be anchored to their previous choices to a greater extent than the Decreasing types.

Overall, the pattern of underadjustment by non-Decreasing types in this game resembles both their behavior in the Monty Hall game (in which the vast majority choose to keep their first door), and their behavior in the 2/3 guessing game, in which their choices over the first and second halves of the game were very similar. Also, as with the Monty Hall game, while distinct SCP types respond in different manners in the multi-period Bayesian updating game, neither final choice nor Nagel's categories correlate with the sum of the squared errors over the 7 rounds of the game.[47]

8 Conclusions

We introduced a new experimental protocol to provide information on provisional choices in games, and hence the process of strategic decision-making. We implemented our SCP treatment in the 2/3 guessing game. We identified a strong connection between time constrained play and play at the corresponding time in the SCP experiment. We found first choices to average close to 50, matching the standard assumption concerning L0 play. While average choices indicate an increase in strategic sophistication as time progresses, we identified significant heterogeneity in this regard. This heterogeneity appears to be informative concerning the ability to update according to Bayes' rule.

We conclude that SCP data provide significant insight into the process of choice

[46]The percentage difference between periods 2 and 3, 3 and 4, 4 and 5, 5 and 6, 6 and 7 for the non-Decreasing types are 8.5%, 6.5%, 12.9%, 14.5% and 9%. For the Decreasing type they are: 16.2%, 23.9%, 25.5%, 25.7% and 23.8%.

[47]This is also the case for 5 of the 7 periods if we look at errors in each period separately.

in unfamiliar games. Given this, it may be worthwhile to gather the corresponding data for a variety of other games in which strategic instincts may be adjusted in the period of contemplation. While we have in the current paper focused on the impact of contemplation time on strategic sophistication, there may be other factors that impact strategic choice and that evolve over time, such as emotions toward other players in the game. We believe that the SCP method may provide insight into many situations of this form, capturing as it does the evolution of perceived optimal decisions as time passes.

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A Instructions for the Choice Process Experiment

We will start with a brief instruction period. If you have any questions during this period, raise your hand. Experiment consists of two parts. You will be given instructions for the next part of the experiment once you finished this part. Anything you earn in the experiment will be added to your show-up fee of $7.

PART I

We will start by describing what kinds of decisions you will be making in this game. We will then describe the rules of the game and the payments in this game.

Your task in this game is to choose a number from those presented on the screen.

The game lasts 180 seconds. At the top right corner of the screen you can see how many seconds are left. At the bottom right corner of the screen there is a "Finished" button. The rest of the screen is filled with buttons representing integer numbers between 1 and 100. They are arranged in decreasing order.

When the game starts, you can select the number by clicking on the button displaying the number that you want. You may click when you want, however many times you want.

The computer will record all the numbers you click on, as well as when you clicked on them.

After 180 seconds, or when you click the finish button, the round will come to an end and you won't be able to change your choice anymore. Just to make clear, if you choose a number and then stay with that number until the end, or instead decide to click on the "Finish" button, it will make no difference.

Only one of the numbers you selected will matter for payment. To determine which one, the computer will randomly choose a second between 0 and 180, each second is equally likely to be chosen. The number you selected at that time will be the one that matters. We will call this number **"Your Number."** Below are two examples.

Example 1

Suppose you chose the button 100 for seconds 0 to 180. Suppose the computer randomly selects second 13 to be the random second.

Since at second 13 you were at button 100, 100 is “Your Number”.

Example 2

Suppose that after 10 seconds you selected the button 62. Suppose then that at second 55 you switched to button 40. Suppose that then at second 90 you switched to button 89 and then clicked on the Finish button.

In this case “Your Number” would be:

- if the computer randomly chooses a number between 0 and 9 seconds: none.
- if the computer randomly chooses a number between 10 and 54 seconds: 62
- if the computer randomly chooses a number between 55 and 89 seconds: 50
- if the computer randomly chooses a number between 90 and 180 seconds: 89

These examples are completely random and do not represent a hint at what you ought to do in this experiment. Note: once a button is clicked on, it becomes highlighted and you do not need to click on it again as it is already selected.

If you have not yet made a selection at the random second the computer chooses, then you cannot win this game.

Also, understand that if at any point you prefer a different number to the one you currently have selected, you should change the button you selected as this would reduce the chances of the less preferred number being recorded as “Your Number.”

The Structure of the Game

A few days ago 8 undergraduate students like yourselves played a game. Your payoff is tied to the choices made by those 8 students, so you need to understand the game they played. We will now distribute the rules of the game these 8 students played and the rules of the game you will be playing.

Your payoff will not depend on the choices made by the people in this room. It depends only on your choice and the choices these 8 students made a few days ago.

[Distribute the second set of instructions face down now. Wait for all to receive a copy. Read it out loud.]

<u>The PAST game the 8 people played:</u>

Each of the 8 students had 180 seconds to choose an integer between 1 and 100 inclusive, which they wrote on a piece of paper. After 180 seconds, we collected the papers. The winner was the person whose number was closest to two thirds of the average of everyone's numbers. That is, the 8 students played among themselves and their goal was to guess two thirds of the average of everyone's numbers.

The winner won $10 and in case of a tie the prize was split.

<u>The game YOU will be playing now:</u>

You will have 180 seconds to choose an integer between 1 and 100 inclusive. You win $10 if you are "better than" those 8 students at determining two thirds of the average of their numbers. That is, you win $10 if **<u>Your Number</u>** is the **closest** to two thirds of the average of the numbers in the past game.

At any point, it is in your best interest to select the button corresponding to what you think is two thirds of the average of the numbers in the past game.

[Game starts right away.]

B Instructions for the Other Games

B.1 Monty Hall (Game 1)

Screen 1
Behind one of these doors is $5. Behind the other two is $0. So, there is only one winning door.
Please choose one of the doors.
Screen 2
You have selected Door < their choice >.
We know which door contains $5.
Before we opend the door you selected, we are going to open one of the doors that contains $0.

[We open one door that contains $0.]

Screen 3
Do you want to keep Door < their choice > or switch to Door < other door >?

B.2 Status-Quo Lotteries (Games 2-4)

The next 3 games of the experiment consist of two stages each. You will first be asked to choose one lottery from a group of alternatives (Stage 1). After you have made your choice, you will be presented with a second group of lotteries. You will have the opportunity to exchange the lottery you chose in the first stage for one of these new lotteries, or to stick with your original choice. The lottery you choose at this time will be your 'final choice' for that game.

Game 2
Screen 1
Please choose one of the following lotteries:

1. $5 for sure.
2. $0 with probability 25% and $4 with probability 75%.
3. $4 with probability 90% and $1 with probability 10%.

Screen 2
You have chosen $5 for sure.
Do you want to keep this lottery or exchange it for one of the lotteries below?

1. $13 with probability 50% and $0 with probability 50%.

2. \$25 with probability 30% and \$0 with probability 70%.

Game 3

Screen 1

Please choose one of the following lotteries:

1. \$10 with probability 50% and \$2 with probability 50%.
2. \$5 with probability 25% and \$1 with probability 75%.
3. \$2 for sure.

Screen 2

You have chosen the lottery that pays \$10 with probability 50% and \$2 with probability 50%.

Do you want to keep this lottery or exchange it for one of the lotteries below?

1. \$14 with probability 50% and \$0 with probability 50%.
2. \$4 for sure.

Game 4

Screen 1

Please choose one of the following lotteries:

1. \$1 with probability 90% and \$3 with probability 10%.
2. \$6 with probability 90% and \$0 with probability 10%.
3. \$4 with probability 90% and \$0 with probability 10%.

Screen 2

You have chosen the lottery that pays \$6 with probability 90% and \$0 with probability 10%.

Do you want to keep this lottery or exchange it for one of the lotteries below?

1. \$10 with probability 65% and \$0 with probability 35%.
2. \$20 with probability 10% and \$2 with probability 90%.

B.3 Multi-Period Bayesian Updating Game (Game 5)

Screen 1

A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

A witness identified the cab as Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

What are the chances that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

Screen 2

A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness identified the cab as Blue.

A second witness comes forward. This witness is independent from the previous one. This witness identifies that the cab was Blue.

What are the chances that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

Screen 3

A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness has identified the cab as Blue. The second witness has identified the cab as Blue.

A third witness comes forward. This witness is independent from the previous ones. This witness identifies that the cab was Blue.

What are the chances that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

Screen 4

A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness has identified the cab as Blue. The second witness has identified the cab as Blue. The third witness has identified the cab as Blue.

A fourth witness comes forward. This witness is independent from the previous ones. This witness identifies that the cab was Green.

What are the chances that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

Screen 5

A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness has identified the cab as Blue. The second witness has identified the cab as Blue. The third witness has identified the cab as Blue. The fourth witness has identified the cab as Green.

A fifth witness comes forward. This witness is independent from the previous ones. This witness identifies that the cab was Blue.

What are the chances that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

Screen 6

A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness has identified the cab as Blue. The second witness has identified the cab as Blue. The third witness has identified the cab as Blue. The fourth witness has identified the cab as Green. The fifth witness has identified the cab as Blue.

A sixth witness comes forward. This witness is independent from the previous ones. This witness identifies that the cab was Green.

What are the chances that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

Screen 7

A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness has identified the cab as Blue. The second witness has identified the cab as Blue. The third witness has identified the cab as Blue. The fourth witness has identified the cab as Green. The fifth witness has identified the cab as Blue. The sixth witness has identified the cab as Green.

A seventh witness comes forward. This witness is independent from the previous ones. This witness identifies that the cab was Blue.

What are the chances that the cab involved in the accident was Blue? Enter

a number between 0 and 100.
You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

B.4 Numeracy questions and Cognitive Reflection Test (Game 6)

Game 6 consists of 9 questions. If this game will be chosen for payment, then for each correctly answered question you will be paid 50 cents.

1. If the chance of getting a disease is 10 percent, how many people out of 1,000 would be expected to get the disease?
2. If 5 people all have the winning numbers in the lottery and the prize is two million dollars, how much will each of them get?
3. Lets say you have $200 in a savings account. The account earns 10 percent interest per year. How much would you have in the account at the end of two years?
4. A store is offering a 15% off sale on all TVs. The most popular television is normally priced at $1000. How much money would a customer save on the television during this sale?
5. Which of the following represents the biggest chance of winning a lottery: a 1 in 100 chance, a 1 in 1000 chance, or a 1 in 10 chance?
6. If a customer saved $10 off a $1000 chair, what percent would the customer have saved off the original price?
7. A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?
8. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?
9. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?

B.5 Risk Attitudes (Game 7)

In game 7 you will have 10 questions. In each question (row), you will be asked to choose Lottery A or Lottery B. If this Game will be chosen for payment, then one of the questions (rows) will be chosen at random and the Lottery that you chose will be played out for you.

Option A	Option B	Your Choice
1/10 of \$2 and 9/10 of \$1.60	1/10 of \$3.85 and 9/10 of \$0.10	
2/10 of \$2 and 8/10 of \$1.60	2/10 of \$3.85 and 8/10 of \$0.10	
3/10 of \$2 and 7/10 of \$1.60	3/10 of \$3.85 and 7/10 of \$0.10	
4/10 of \$2 and 6/10 of \$1.60	4/10 of \$3.85 and 6/10 of \$0.10	
5/10 of \$2 and 5/10 of \$1.60	5/10 of \$3.85 and 5/10 of \$0.10	
6/10 of \$2 and 4/10 of \$1.60	6/10 of \$3.85 and 4/10 of \$0.10	
7/10 of \$2 and 3/10 of \$1.60	7/10 of \$3.85 and 3/10 of \$0.10	
8/10 of \$2 and 2/10 of \$1.60	8/10 of \$3.85 and 2/10 of \$0.10	
9/10 of \$2 and 1/10 of \$1.60	9/10 of \$3.85 and 1/10 of \$0.10	
10/10 of \$2 and 0/10 of \$1.60	10/10 of \$3.85 and 0/10 of \$0.10	

C Results of the Other Games

Results of the Status-Quo Games

Table 7 shows the percentage of subjects who switch to a different lottery in the second stage (virtually all subjects chose the non-dominated lottery in the first stage) of each of the status-quo games (Games 2-4).

	Non Decreasing % Keep	Decreasing % Keep
Game 2	40.5	38.9
Game 3	59.5	55.6
Game 4	59.5	61.1

Table 7: Status-quo games

Tests of proportions and Probit regressions with Decreasing and Risk-attitude as independent variables show that there the behavior of our subjects does not seem to depend on whether they are part of the Decreasing group or not.[48]

Risk Measures

Ordered Probit regressions show that Final choice or belonging to the Decreasing group do not correlate with risk preferences. The average (median, standard deviation) switching point from Lottery A to Lottery B for the Decreasing group is 6.4 (6, 1.8) and for the non-Decreasing group is 6.5 (7, 1.7). A ranksum test also show that there is no difference in the distribution of switching points between the Decreasing and non-Decreasing groups.

Numeracy Measures

Ordered Probit regressions show that final choice or belonging to the Decreasing group do not correlate with our ability measures. The dependent variable was a subject's score, where each subject's score was simply the number of correct answers. The average (median, standard deviation) score for the Decreasing group is 7.1 (7, 1.6) and for the non-Decreasing group is 6.7 (7, 1.6). A ranksum test also show that there is no difference in the distribution of number of correct responses between the Decreasing and non-Decreasing groups.

[48]Risk-attitude has a significant and "appropriately-signed" coefficient for Games 2 and 4. Regressions using final choice did not produce any results either.

D Additional Results on the Comparison Between the Standard Experiments and Nagel (1995) and Ho, Camerer and Weiglet (1998)

In Table 8 we report summary statistics for the 30 and 180 second treatments of the standard 2/3 guessing game experiments. We include corresponding statistics from the classical experiments of Nagel (1995) and Ho, Camerer and Weiglet (1998).

	mean choice	st deviation	# of obs
Standard Experiment 30 sec. treatment	42.83	20.13	66
Standard Experiment 180 sec. treatment	36.35	20.24	62
Nagel (1995)	37.2	20	66
Ho, Camerer & Weiglet (1998)	38.9	24.7	69

Table 8: Summary Statistics of the final choices in the Standard Experiment

As Table 8 shows, the results for the Standard Experiment 180 second treatment are close to standard results from previous experiments. However the results for the Standard Experiment 30 second treatment are substantially different, as further indicated by the histograms in Figures 1(a) and 1(b). The average and median choices are higher in the 30 second treatment than in the 180 second treatment.

We measure strategic sophistication in our Standard Experiments using two distinct techniques: that of Nagel (1995) and that of Camerer, Ho and Chong (2004). In Table 9 we report the classification of final choices according to Nagel's technique in the 30 and 180 seconds treatments and compare it to that obtained by Nagel (1995) in her original experiments.[49] The results show that the distribution of types after 180 seconds is very similar to the distribution of types obtained by Nagel (1995), while the distribution of types after 30 and after 180 seconds is significantly different, with more sophisticated choices observed in the longer treatment (180 seconds).

	Standard Experiment 30 sec. treatment	Standard Experiment 180 sec. treatment	5 minutes Nagel (1995)
L0	15.2%	9.7 %	7.5%
L1	13.6%	25.8%	26%
L2	10.6%	17.7%	24%
L3	4.6%	8.1%	2%
% captured by L0-L3 definition	43.9%	63.3%	59.9%

Table 9: Distribution of types (Nagel) in the Standard and Nagel (1995) Experiments.

Note that when there is more time to decide, more subjects are captured by the Nagel classification. This supports the claim that choices are more sophisticated as time goes

[49]The estimates from Camerer, Ho and Chong (2004) are in Table 2.

by: being closer to uniform, many early choices fall outside the relevant intervals.[50]

[50]Nagel's classification starts from the premise that Level 0 players choose 50. Nagel then constructs neighborhood intervals of $50p^n$, where p is the multiplier used in the game ($p = \frac{2}{3}$ in our case) and n represents the level of reasoning ($n = 0, 1, 2, ...$). The numbers that fall between two neighborhood intervals of $50p^{n+1}$ and $50p^n$ are called interim intervals. To determine the boundaries of adjacent intervals a geometric mean is used. Thus the neighborhood interval of $50p^n$ have boundaries of $50p^{n+\frac{1}{4}}$ and $50p^{n-\frac{1}{4}}$ rounded to the nearest integers. The exception is Level 0, which is truncated at 50. Nagel classifies as Level 0 choices between 45 and 50, Level 1 those between 30 and 37, Level 2 between 20 and 25, and Level 3 those between 13 and 16.

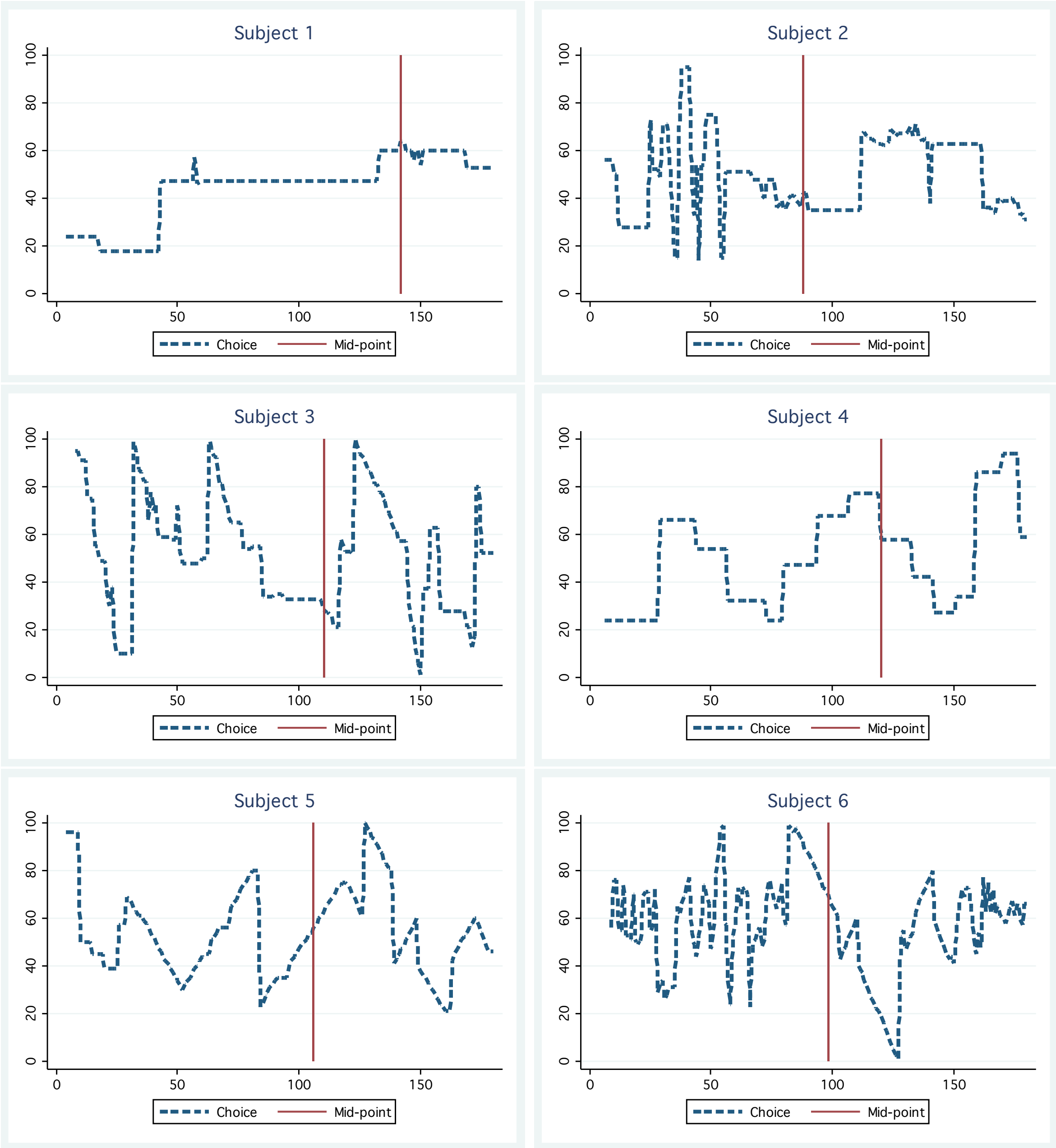
E Marginal Effects Probit Regressions

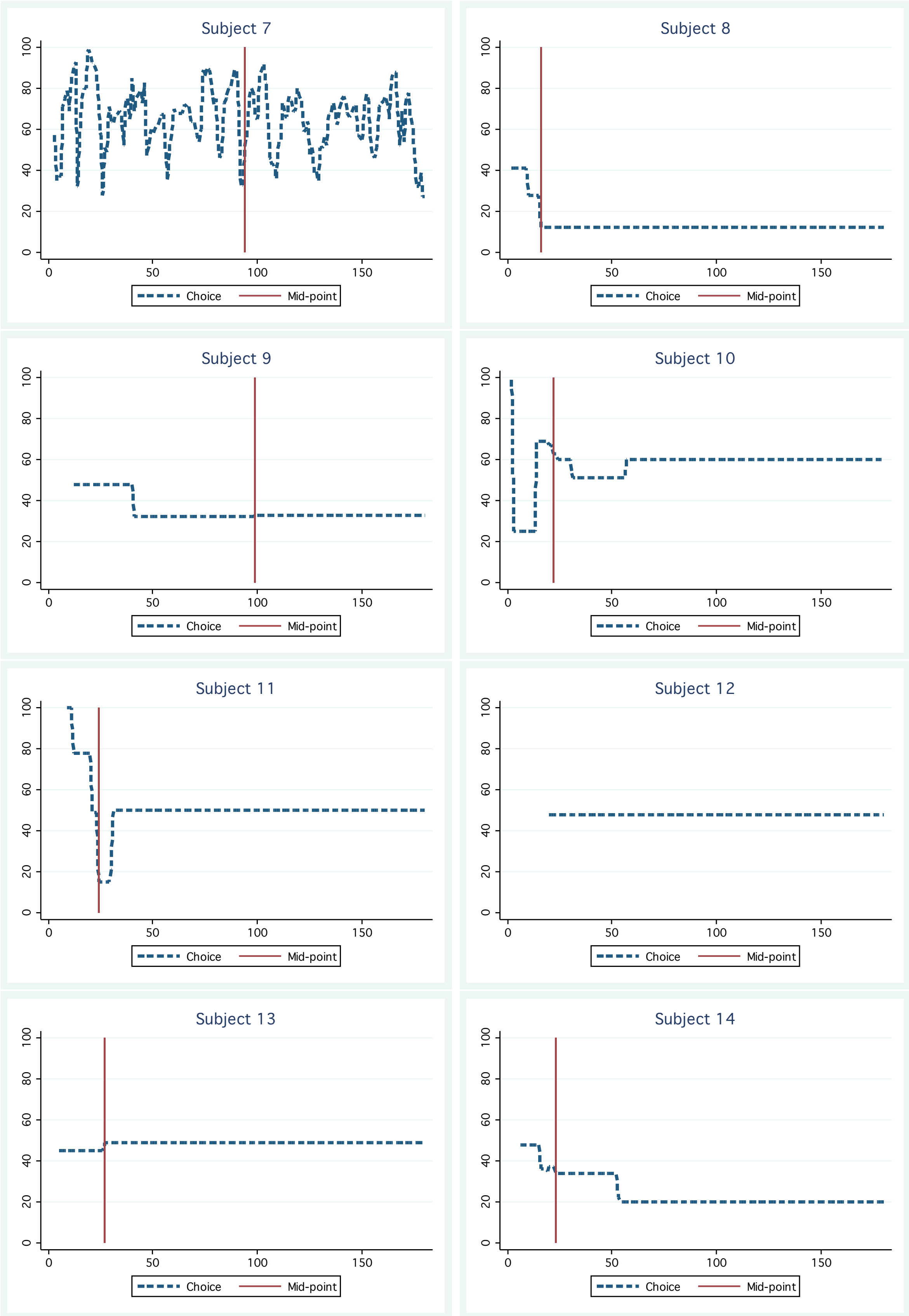
	Regression 3	$\bar{x}$	Regression 4	$\bar{x}$
Decreasing	$-0.2540^{**}(0.132)$	.3	$-.846^{***}$ (.165)	.3
Dec. $\times$ Final Choice			0.028^{**} (0.0132)	7.21
Final choice			-0.0017 (0.004)	36.73

Coefficient and standard deviation is reported in the parenthesis
** $-$ significant at 5% *** $-$ significant at 1%

Table 10: Predicting behavior in the Monty Hall Game.

F Individual Paths

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Subject 9
Subject 10
Subject 11
Subject 12
Subject 13
Subject 14
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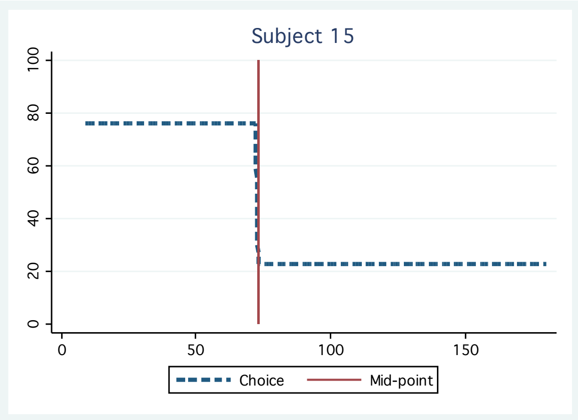
0 50 100 150
Choice
Mid-point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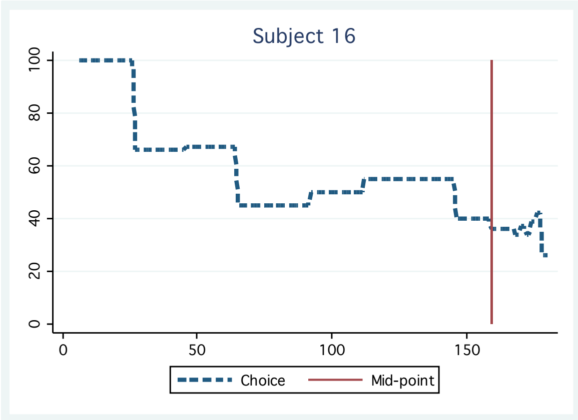
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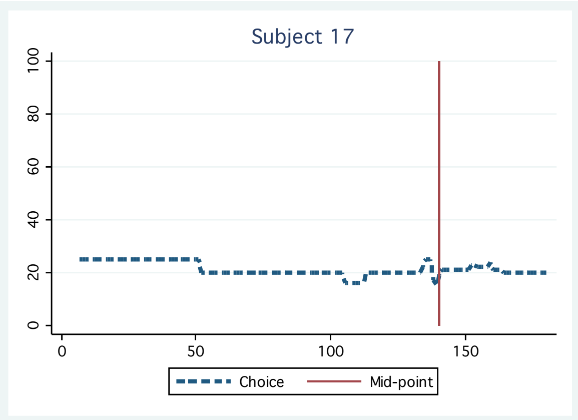
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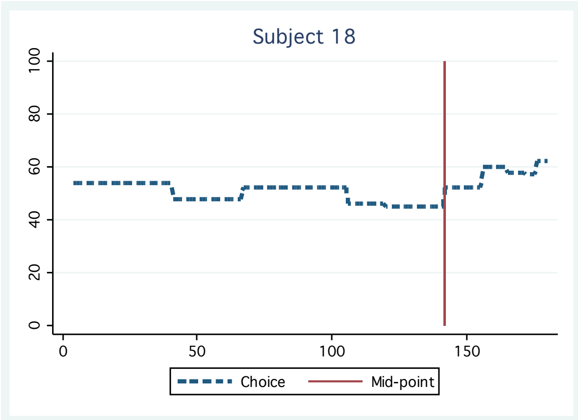
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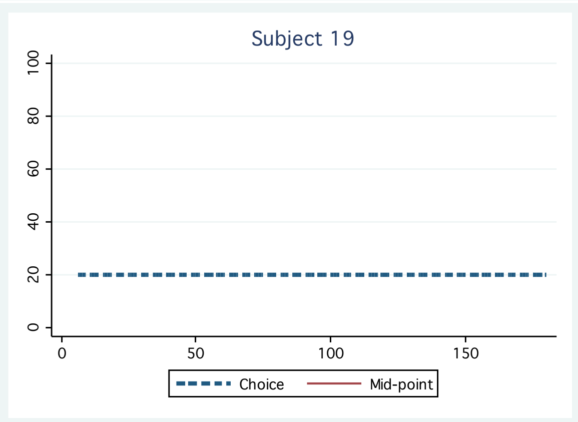
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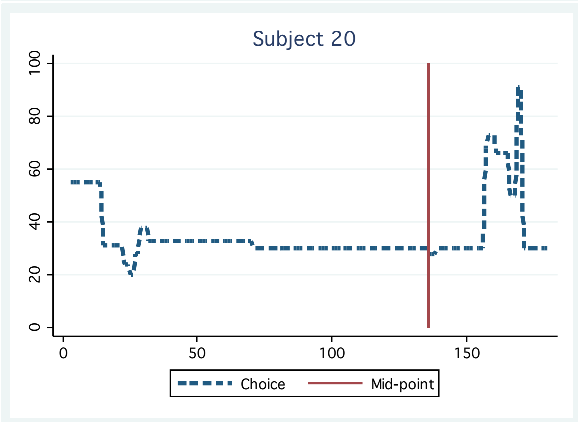
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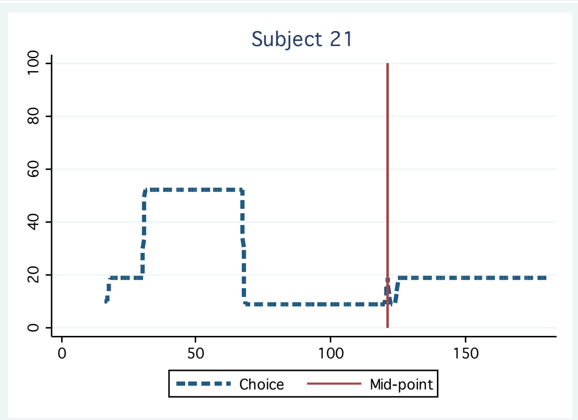
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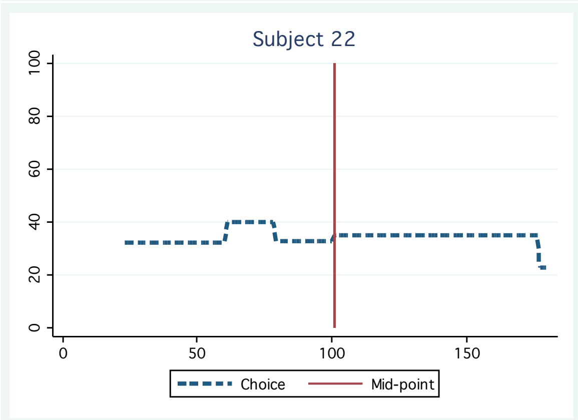
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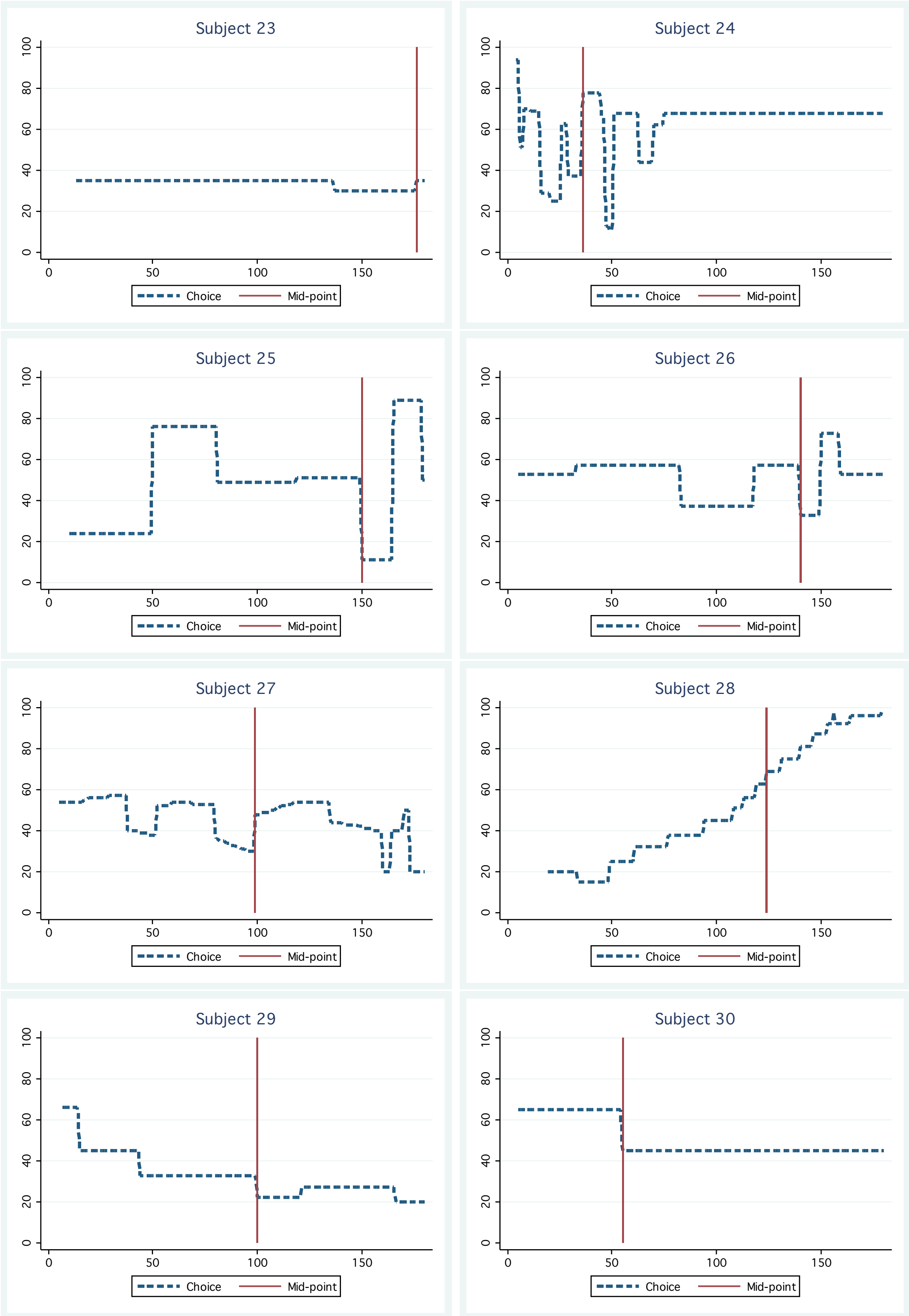
Choice Mid-point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Subject 25
Subject 26
Subject 27
Subject 28
Subject 29
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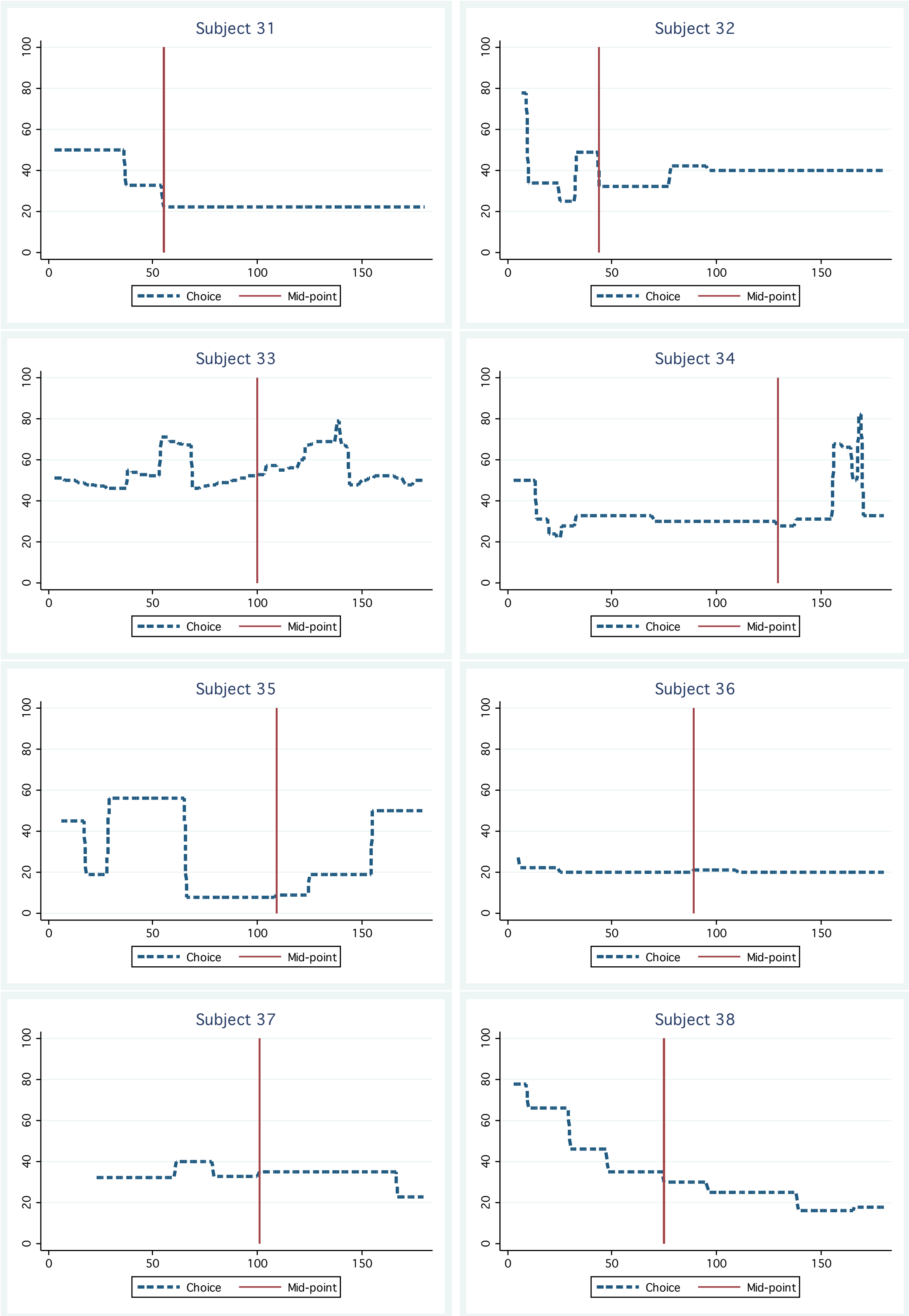
100
150
Choice
Mid-point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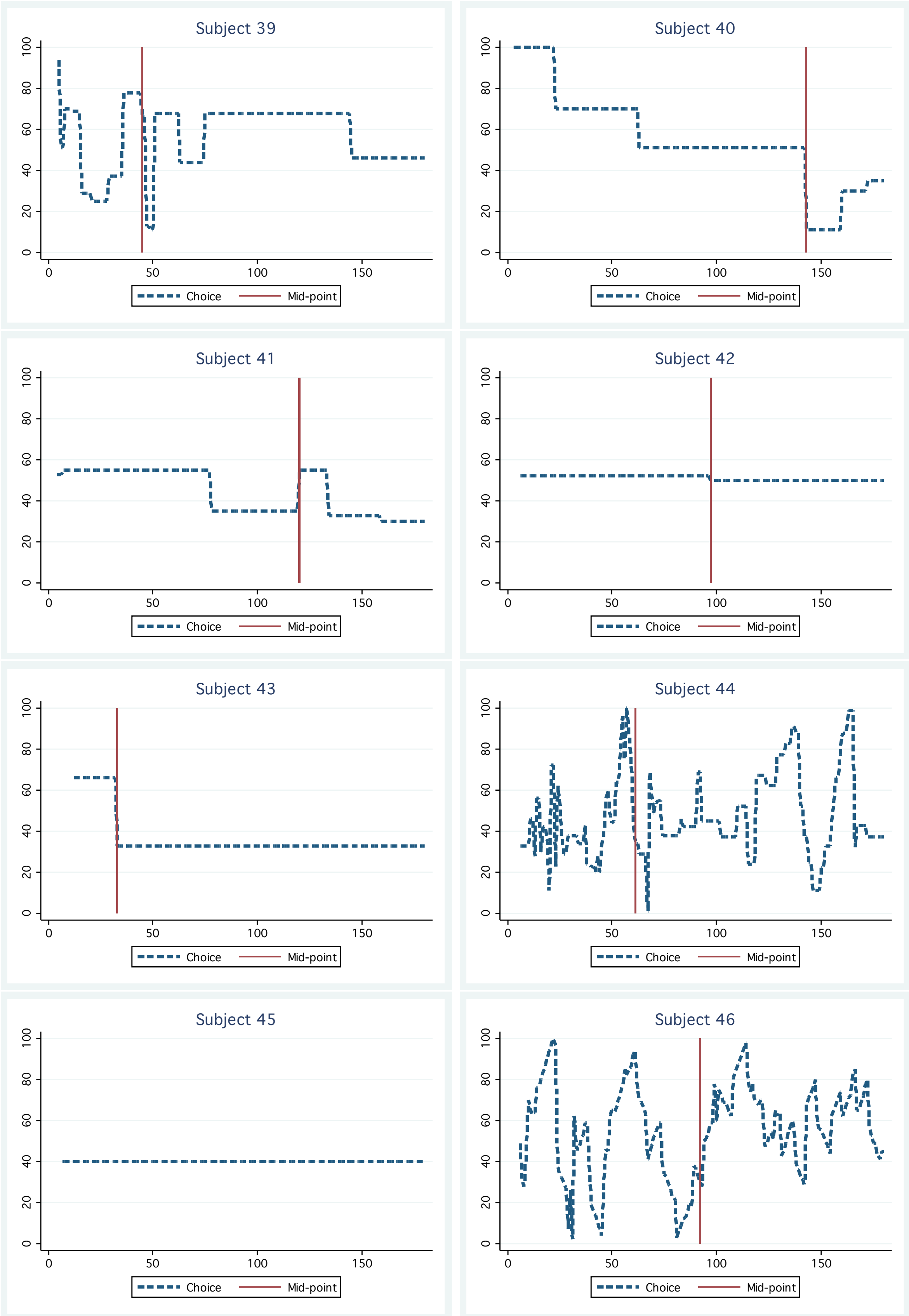
Choice
Mid-point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80
100
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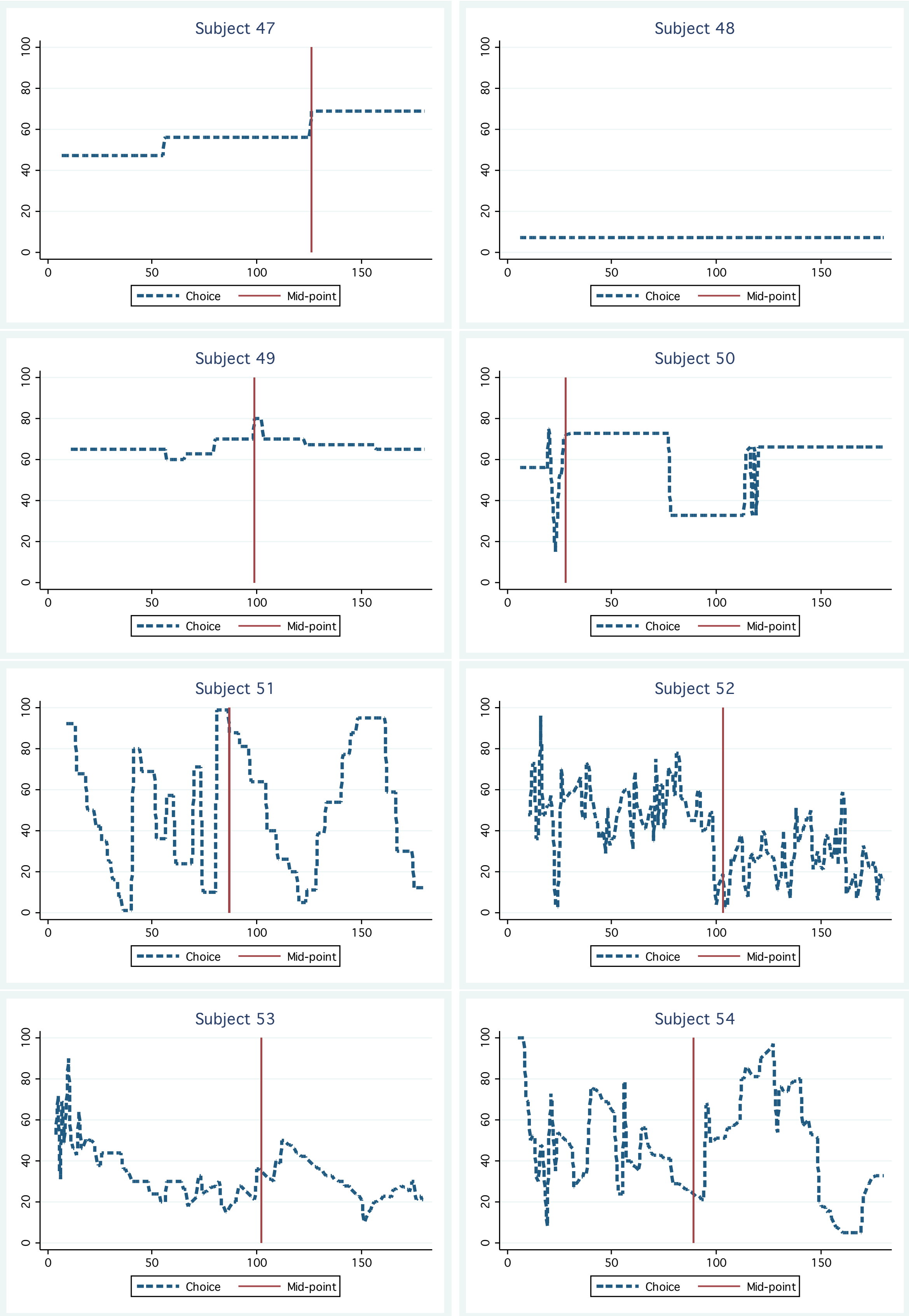
100
150
Choice
Mid-point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Subject 49
Subject 50
Subject 51
Subject 52
Subject 53
Subject 54
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0 50 100 150
Choice
Mid-point

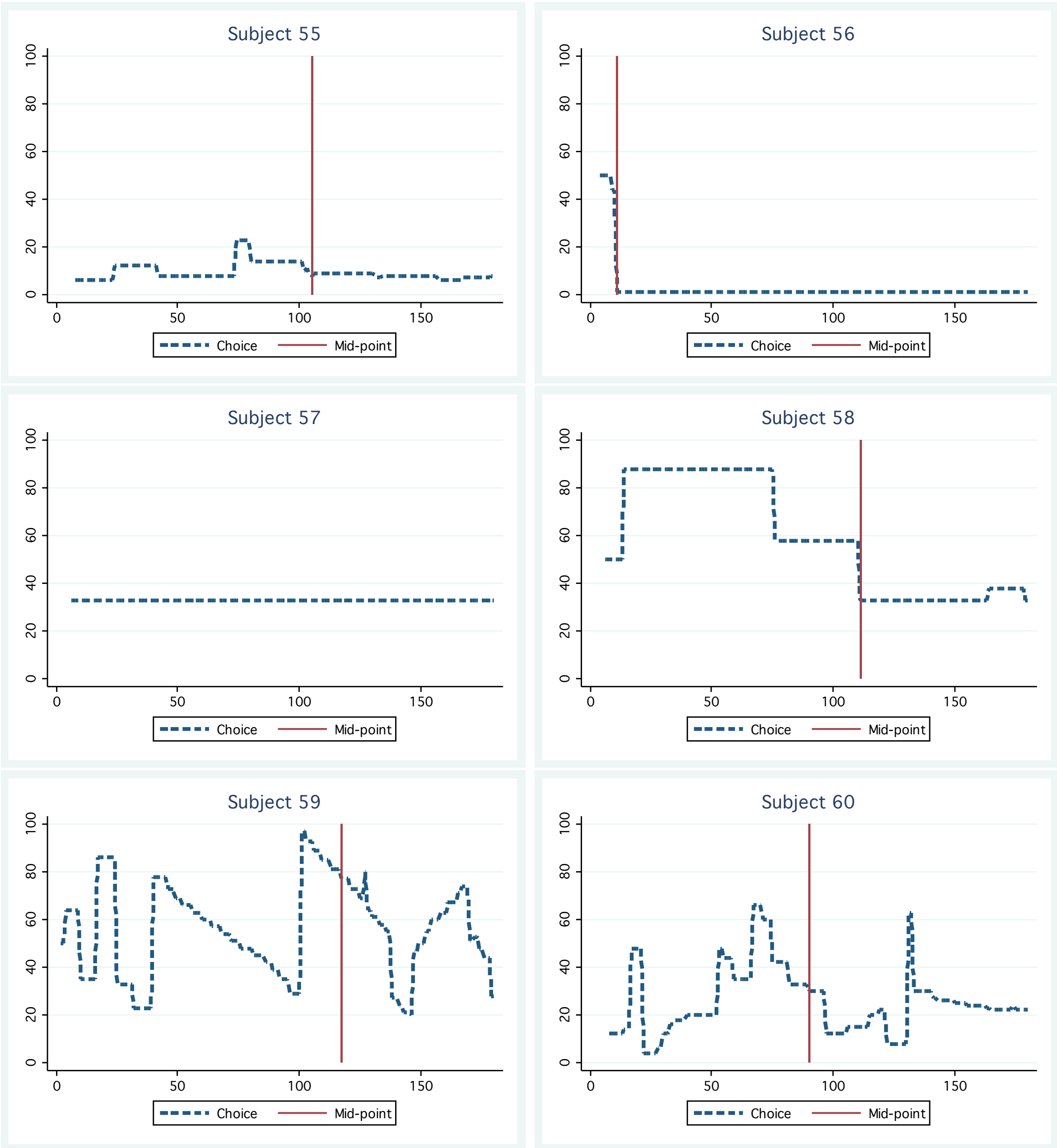

Figure 7: Individual time paths: Choices over time with mid-point.